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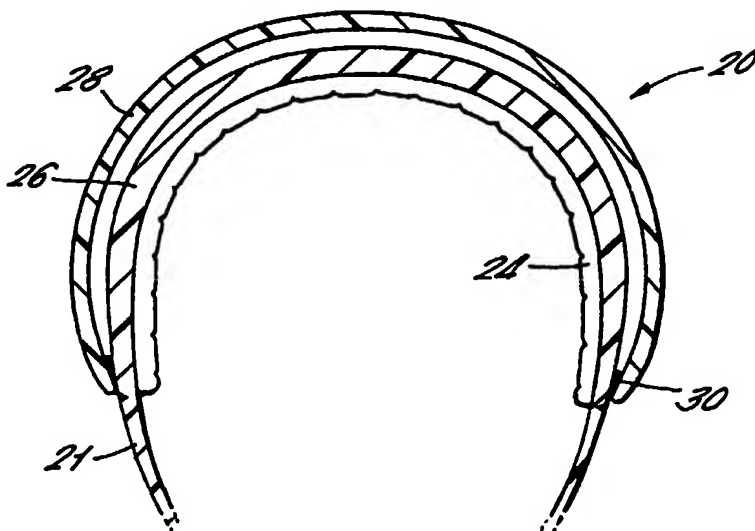
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(54) Title: **PROTECTIVE HEADGEAR AND PROTECTIVE ARMOUR AND A METHOD OF MODIFYING PROTECTIVE HEADGEAR AND PROTECTIVE ARMOUR**



(57) Abstract: The present invention provides protective headgear comprising a shell (26) having an inwardly facing surface which in use faces the head (10) of a user of the headgear and an outwardly facing surface which in use faces away from the head (10) of a user. An outer layer (28) overlies at least a portion of the outwardly facing surface of the shell (26) and rupturing means (30) is provided for fixedly attaching the outer layer (28) to the remainder of the headgear at one or more locations. The rupturing means (30) is configured so as to fail when a force greater than a selected threshold is received on an outer surface (28) of the headgear which acts in an at least part tangential direction to rotate the headgear and the head (10) of the user. Upon failure of the

rupturing means (30) at the one or more locations, the received force causes at least part of the outer layer (28) receiving the force to move relative to the shell (26) in a manner which is similar to the protective movement of the human scalp (18) relative to the skull (16). The present invention also relates to protective armour (100) and to a method of modifying protective headgear and protective armour.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

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**PROTECTIVE HEADGEAR AND PROTECTIVE ARMOUR AND A METHOD  
OF MODIFYING PROTECTIVE HEADGEAR AND PROTECTIVE ARMOUR**

5           The present invention relates to protective  
headgear such as safety helmets for use when  
motorcycling or pedal cycling, or when taking part in  
hazardous sporting activities such as climbing, horse  
riding or white water rafting. The present invention  
10 is also relevant in an industrial context for safety  
helmets used on construction sites, in factories and  
in military applications. Indeed, the present  
invention may be employed in any environment where a  
form of protective headgear is desired which is  
15 lightweight and unencumbering for the user whilst  
being effective in preventing or minimising the  
effects of an impact to the head. A particular  
feature of the present invention is its ability to  
mimic characteristics of the human head in order to  
20 provide protection against injury.

          The present invention also relates to protective  
armour such as body armour used by riot police and the  
armed forces.

25

          Various forms of head protection are known in the  
art which have sought to diffuse and spread the impact  
of falls or blows by constructing protective helmets  
of hard materials. It is usual to provide a  
30 polystyrene or similar foam liner or webbing support  
inside such helmets both for energy absorption and for  
comfort. However, many such "hard hats" have limited  
capacity for energy absorption and simply transmit the  
forces of an impact to the head of a user, albeit over  
35 a wider area. Worse still, certain helmets have  
allowed the source of an impact to come into direct

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contact with the head of a user once the hard material has been sacrificed or breached, particularly in cases of severe impact. For example, in US-A-3946441 there is disclosed a safety helmet which comprises a primary  
5 shell having tough impact resisting properties and a second outer shell formed from a brittle material which is designed to fracture even upon minor impacts.

Protective armour is also known in the art and in  
10 the past one particular use of such armour has been to protect the body when playing hazardous or contact sports. In US-A-3500472 there is disclosed a protective garment having cushioning means which are inserted into pockets on the protective garment and  
15 inflated. In use, the garment is designed to restrict any relative movement between the cushioning means and the pocket means when the garment is subjected to impacts.

20 The present invention takes note of and incorporates certain protective features of the human head, which in itself is capable of absorbing and dissipating considerable amounts of energy, thereby protecting against impacts. Protective headgear and  
25 protective armour incorporating such features is disclosed by the applicant in EP 0790787. The present invention is concerned with improvements in the apparatus and methods disclosed in EP 0790787.

30 The present invention provides, in a first aspect, protective headgear comprising:

a shell having an inwardly facing surface which in use faces the head of a user of the headgear and an outwardly facing surface which in use faces away from  
35 the head of a user;

an outer layer which overlies at least a portion of the outwardly facing surface of the shell; and

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rupturing means for fixedly attaching the outer layer to the remainder of the headgear at one or more locations, wherein:

5 the rupturing means is configured so as to fail when a force greater than a selected threshold is received on an outer surface of the headgear which acts in an at least part tangential direction to rotate the headgear and the head of the user, and  
10 upon failure of the rupturing means at the one or more locations, the received force causes at least part of the outer layer receiving the force to move relative to the shell in a manner which is similar to the protective movement of the human scalp relative to the skull.

15

In a second aspect, the present invention provides protective headgear comprising:

20 a shell having an inwardly facing surface which in use faces the head of a user of the headgear and an outwardly facing surface which in use faces away from the head of a user;

an outer layer which overlies at least a portion of the outwardly facing surface of the shell; and

25 means for fixedly attaching the outer layer to the remainder of the headgear at one or more locations, wherein

30 the outer layer is configured so as to yield when a force greater than a selected threshold is received on an outer surface of the headgear which acts in an at least part tangential direction to the outer surface of the headgear to rotate the headgear and the head of the user, and

35 upon yielding of the outer layer, the received force causes at least part of the outer layer receiving the force to move relative to the shell in a manner which is similar to the protective movement of the human scalp relative to the skull.

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In a third aspect, the present invention provides protective armour comprising:

5 a base layer having an inwardly facing surface which in use faces the body of a user of the armour and an outwardly facing surface which in use faces away from the body of a user;

10 an outer layer which overlies at least a portion of the outwardly facing surface of the base layer; and rupturing means for fixedly attaching the outer layer to the remainder of the armour at one or more locations, wherein:

15 the rupturing means is configured so as to fail when a force greater than a selected threshold is received on an outer surface of the armour which acts in an at least part tangential direction to rotate the armour and the body of the user, and

20 upon failure of the rupturing means at the one or more locations, the received force causes at least part of the outer layer receiving the force to move relative to the base layer in a manner which is similar to the protective movement of the human scalp relative to the skull.

25 In a fourth aspect, the present invention provides protective armour comprising:

30 a base layer having an inwardly facing surface which in use faces the body of a user of the armour and an outwardly facing surface which in use faces away from the body of a user;

an outer layer which overlies at least a portion of the outwardly facing surface of the base layer; and means for fixedly attaching the outer layer to the remainder of the armour at one or more locations, wherein:

35 the outer layer is configured so as to fail when a force greater than a selected threshold is received

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on an outer surface of the armour which acts in an at least part tangential direction to the outer surface of the armour to rotate the armour and the body of the user, and

5        upon failure of the outer layer, the received force causes at least part of the outer layer receiving the force to move relative to the base layer in a manner which is similar to the protective movement of the human scalp relative to the skull.

10

In a fifth aspect, the present invention provides a method of modifying existing protective headgear wherein:

15        an outer layer is provided to overlie at least a portion of an outwardly facing surface of the existing protective headgear; and

      rupturing means are provided for fixedly attaching the outer layer to the remainder of the existing protective headgear at one or more locations,

20        the rupturing means being configured so as to fail when a force greater than a selected threshold is received on an outer surface of the modified headgear which acts in an at least part tangential direction to rotate the modified headgear and the head of the user, and

25        upon failure of the rupturing means at the one or more locations, the received force causes at least part of the outer layer receiving the force to move relative to the outwardly facing surface of the existing protective headgear in a manner which is

30        similar to the protective movement of the human scalp relative to the skull.

In a sixth aspect, the present invention provides a method of modifying existing protective headgear wherein:

35        an outer layer is provided to overlie at least a

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portion of an outwardly facing surface of the existing protective headgear; and

means is provided for fixedly attaching the outer layer to the remainder of the existing protective headgear at one or more locations,

the outer layer being configured so as to fail when a force greater than a selected threshold is received on an outer surface of the modified headgear which acts in an at least part tangential direction to the outer surface of the modified headgear to rotate the modified headgear and the head of the user, and upon failure of the outer layer, the received force causes at least part of the outer layer receiving the force to move relative to the outwardly facing surface of the existing protective headgear in a manner which is similar to the protective movement of the human scalp relative to the skull.

In a seventh aspect, the present invention provides a method of modifying existing protective armour wherein:

an outer layer is provided to overlies at least a portion of an outwardly facing surface of the existing protective armour; and

rupturing means are provided for fixedly attaching the outer layer to the remainder of the existing protective armour at one or more locations,

the rupturing means being configured so as to fail when a force greater than a selected threshold is received on an outer surface of the modified armour which acts in an at least part tangential direction to rotate the modified armour and the body of the user, and

upon failure of the rupturing means at the one or more locations, the received force causes at least part of the outer layer receiving the force to move relative to the outwardly facing surface of the



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existing protective armour in a manner which is similar to the protective movement of the human scalp relative to the skull.

5           In an eighth aspect, the present invention provides a method of modifying existing protective armour wherein:

          an outer layer is provided to overlies at least a portion of an outwardly facing surface of the existing protective armour; and

10           means is provided for fixedly attaching the outer layer to the remainder of the existing protective armour at one or more locations,

          the outer layer being configured so as to fail

15           when a force greater than a selected threshold is received on an outer surface of the modified armour which acts in an at least part tangential direction to the outer surface of the modified armour to rotate the modified armour and the body of the user, and

20           upon failure of the outer layer, the received force causes at least part of the outer layer receiving the force to move relative to the outwardly facing surface of the existing protective armour in a manner which is similar to the protective movement of

25           the human scalp relative to the skull.

Preferred embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings, in which:

30           Figure 1 is a schematic representation of a human head in coronal cross section;

          Figure 2 is an enlarged detail view of the coronal cross section of Figure 1;

          Figure 3 illustrates a typical form of protective headgear according to the present invention in use;

35           Figure 4 is a cross section of a first embodiment of protective headgear according to the present

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invention;

Figure 5 is an enlarged detail view illustrating a method of attachment of an outer layer to a lower peripheral edge of the protective headgear of Figure 4;

Figures 6a, 6b and 6c are detail cross section views illustrating alternative methods of attachment of an outer layer to a lower peripheral edge of the protective headgear according to the present invention;

Figures 7a, 7b and 7c are perspective views (from above) illustrating typical distributed attachment locations of an outer layer to the protective headgear of Figures 6a, 6b and 6c respectively;

Figures 8a and 8b are detail views of a lower peripheral edge of an alternative embodiment of protective headgear according to the present invention, illustrating an outer layer in first and second positions (before and during/after impact);

Figures 9a, 9b and 9c are detail views of a lower peripheral edge of a further embodiment of protective headgear according to the present invention, illustrating successive positions of an outer layer (before, during and after impact);

Figures 10a and 10b are detail views of a lower peripheral edge of a yet further embodiment of protective headgear according to the present invention, illustrating first and second positions of an outer layer (before and during/after impact);

Figure 11 is a schematic representation illustrating preferred stress/strain characteristics of an outer layer of the protective headgear of Figures 4 and 5;

Figure 12 is a schematic representation illustrating preferred stress/strain characteristics of an outer layer of the protective headgear of Figures 8a and 8b;

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Figure 13 is a schematic representation illustrating preferred stress/strain characteristics of an outer layer of the protective headgear of Figures 9a, 9b and 9c, and of Figures 10a and 10b;

5        Figure 14 is a schematic illustration of body armour according to the present invention;

Figures 15 is a cross section through the body armour of Figure 14; and

10       Figures 16a, 16b, 16c, 16d and 16e are detail cross section views illustrating alternative methods of attachment of an outer layer to a base layer of the protective armour according to the present invention.

Referring first to Figure 1, there can be seen a  
15       schematic representation of the human head 10 in coronal cross section. The brain 12 is surrounded by cerebro-spinal fluid 14 and both are contained within the skull 16. On the outside of the skull 16 is the scalp 18. An enlarged detail view of the coronal  
20       cross section of Figure 1 is illustrated in Figure 2.

The protective features of the human head 10 are as follows:

25       **The Scalp**

The scalp 18 is a firm fibrous layer which is substantially inelastic in shear but elastic when subjected to loading in the normal direction. Of  
30       particular importance is the fact that the scalp 18 is not attached firmly to the skull 16 but is instead free to move relative to the skull 16 by limited distances before it begins to tear. The ability of the scalp 18 to move relative to the skull 16 is  
35       important because it is this mechanism which helps counter the effects of tangential components of force in an impact, the brain 12 being particularly

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susceptible to damage from sudden rotational motion relative to the skull 16. The elasticity of the scalp 18 in the normal direction allows for compression which serves to absorb energy from impacts having a normal component of force.

### The Skull

The skull 16 is composed of two layers of dense, compact bone 15 "sandwiching" a layer of spongy cancellous bone 17. This structure provides a hard surface 15 for energy dissipation, allowing a degree of compression or crushing of the cancellous bone 17 for energy absorption and also spreading the area over which an impact acts. The cancellous bone 17 may also allow a degree of distortion of the skull 16 before any fracture occurs.

### The Cerebro-Spinal Fluid

The cerebro-spinal fluid 14 surrounding the brain 12 acts as a further energy absorbing element, cushioning the brain 12 from movements within the cranium. Blows or impacts to the head 10 project the brain 12 towards the cranium, and the resultant displacement of incompressible cerebro-spinal fluid 14 acts as a decelerating medium, absorbing energy.

By mimicking certain of the above protective features of the human head 10, the protective headgear and protective armour of the present invention can be effective in attenuating, and in certain cases neutralising, both normal and tangential components of force sustained during an impact.

Figure 3 illustrates a first embodiment of protective headgear according to the present invention

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in the form of a cycle helmet 20 secured to the head  
10 of a user via a chin strap 21. It will be  
appreciated that the protective headgear of the  
present invention may take the form of other  
5 embodiments such as a traditional "hard hat" or  
motorcycle helmet, the latter more fully enclosing the  
head 10 of the user. Other known means for securing  
protective headgear to the head of a user may be  
utilised in the present invention. Impacts received  
10 on the outer surface of the helmet 20 will have  
tangential  $\alpha$  and normal  $\beta$  force components.

Figures 4 and 5 illustrate in cross section the  
helmet 20 of Figure 3 which can be seen to comprise  
15 an outer layer 28, a shell 26, and an inner liner 24.

Whilst not essential, inner liner 24 may be  
provided inside of the shell 26 to interface with a  
user's head 10. The liner 24 can serve to mimic the  
20 fluid suspension provided by the cerebro-spinal fluid  
14 and/or ensure a more comfortable and safer fit of  
the helmet 20 upon the head 10 of the user.  
Preferably, inner liner 24 comprises a flexible sac  
filled with an appropriately viscous liquid (not  
25 shown) which will be affixed to the inner surface of  
the shell 26 using any conventional fixing means (e.g.  
by bonding with an adhesive or by mechanical  
fasteners). Since fluid in a unicellular sac would  
gravitate to the lower peripheral edge of the helmet  
30 20, compartmentalisation may be necessary to allow a  
suitable mode of displacement of fluid under impact.  
Flow control mechanisms between compartments can be  
included to control flow between the compartments.  
The flow control mechanisms prevent flow of fluid  
35 between compartments in normal use but allow flow of  
fluid between compartments when the helmet 20 is  
subject to an impact. The interconnection of

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compartments will help development of a uniform pressure in all of the compartments, thereby spreading the effect of an impact over a large area. The fluid in the inner liner 24 may be a viscous or aqueous fluid and acts to damp motion of the head 10 of a user relative to the helmet 20 when the helmet 20 is subject to an impact. The flow control means could comprise lines of weakness in walls dividing the compartments, the walls remaining intact to seal off the compartments in normal use but the lines of weakness breaking to form apertures in the walls (and thus allow flow of fluid) in impact conditions. In an alternative embodiment, a "bubble pack" type inner liner 24 can be provided either with a liquid filling, a liquid and gas combination, or solely a gas filling.

In addition, a thin polystyrene or similar liner (not shown) bonded or otherwise affixed on the inside face of the flexible sac inner liner 24 could be used to maintain the shape of and thus the fluid distribution within the sac in which case compartmentalisation of the sac will not necessarily be used. The thin polystyrene or similar liner could be designed to fully enclose the flexible sac.

Also, an additional layer or layers (not shown) may be interposed between the shell 26 and the flexible sac inner liner 24. Indeed, an additional layer or layers may also or alternatively be provided on the inside face of the flexible sac inner liner 24. The additional layer or layers may take the form of any conventional lining material used in protective headgear known in the art, such as low density foam or combinations of low and higher density foams.

Alternatively, the inner liner 24 may instead

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take the form of any conventional energy absorbing lining material used in protective headgear known in the art and omit the flexible sac altogether. This inner liner 24 may be a foamed material having  
5 inherent compliance or alternatively a webbing material commonly used in hard hats for the construction industry. Indeed, the inner liner 24 may comprise a number of discrete layers or be formed as a laminate material. For example, one such modification  
10 involves providing two layers of plastic foam, in combination with a polystyrene liner, either both outside the polystyrene liner, or one outside and the other inside the polystyrene liner. These foam layers can be either low density or combinations of low and  
15 higher density foams. It will be appreciated from the above that many different alternatives and combinations of inner liner 24 are envisaged for the present invention.

20 The shell 26 mimics the skull 16 and thus provides a hard surface for energy dissipation (similar to the compact dense bone 15 of the skull 16) whilst allowing a degree of compression or crushing to facilitate increased energy absorption (similar to the  
25 cancellous bone 17 of the skull 16). Using conventional manufacturing techniques, such properties can be achieved either in a single material or in a composite or laminate structure. In testing, suitable materials for the shell 26 have been found to include  
30 polypropylene, polycarbonate, ABS, polycarbonate/ABS blend, high density polyethylene (HDPE), carbon fibre composites, glass reinforced plastics, Zytel (a nylon manufactured by DuPont), Celstran (a long strand  
glass, carbon or aramid fibre material in a modulus  
35 carrier such as polypropylene, polyethylene, polycarbonate, ABS, TPU or nylon), Twintex (glass fibre reinforced polypropylene manufactured by

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Vetrotex), Curv PP (a polypropylene fibre reinforced material manufactured by BP), and Kevlar composites (aramid fibres in a resin carrier).

5           Outer layer 28 is designed to mimic the scalp 18. Accordingly, in a first embodiment, there is provided an outer layer 28 which is substantially inelastic in shear but elastically compressible when subjected to forces in the normal direction (similar to the scalp  
10 18). However, it has been found in testing that a second embodiment comprising an outer layer 28 which is substantially elastic both in shear and when subjected to forces in the normal direction can also be effective. Accordingly, when selecting suitable  
15 material(s) for the outer layer 28, consideration is given both to the desired mechanical properties of the material(s) in question and to the desired mode of operation of the protective headgear. In testing, suitable materials for the outer layer 28 have been  
20 found to include thermoplastic elastomers such as Santoprene (manufactured by Advanced Elastomer Systems in a range of grades), Hytrel in a solid or foamed form, thermoset elastomers such as polyurethane elastomers (typically in the hardness range 50 shore A  
25 to 70 shore D), High Q (a rubber manufactured by Astron), sorbothane, natural or synthetic rubbers or plasticised foams, low or high density polyethylene (LDPE or HDPE) as well as conventional thermoplastic and thermosetting plastics well known in the art. The  
30 outer layer 28 may be optionally reinforced with high stiffness, low elongation fibres such as glass, carbon or aramid (Kevlar) fibres in order to reduce the overall elasticity of this outer layer. Such fibre reinforcement may take the form of random or  
35 unidirectional fibres, woven or knitted fabrics or scrims which are then moulded into the outer layer.



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It is envisaged that bespoke composite or laminate structures may be beneficially employed in order to obtain optimum mechanical properties and performance characteristics of the protective headgear. For example, in achieving an inelastic outer layer 28 which is compressible in the normal direction, a substantially inelastic layer (both in shear and in the normal direction) may be combined with an elastic layer such that the resulting structure is substantially inelastic in shear but is capable of elastic compression in the normal direction. Suitable composite or laminate structures may be manufactured using standard methods well known in the art including, for example, in-mould, co-moulding (or bi-moulding), glass scrim and co-extrusion techniques.

Since the outer layer 28 could be a porous material, waterproofing may be desirable to prevent water being absorbed and detrimentally affecting the desired mechanical properties of the helmet 20. This could be achieved using conventional waterproofing techniques such as spray on compositions, or by the superimposition (not shown) of a thin but durable layer which is impervious to water, or by both methods. Additionally, where it is desirable to reduce the coefficient of friction of the outer layer 28, the waterproofing treatment selected could serve this purpose also. Alternatively, where waterproofing is not required or desired, only a low coefficient of friction material or layer may be superimposed on the outer layer 28.

In order to reproduce the beneficial protective features of the human head 10, attachment of the outer layer 28 to the hard shell 26 is critical. Several modes of attachment of outer layer 28 to the hard

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shell 26 are envisaged and will now be described in turn.

In the embodiment illustrated in Figures 4 and 5, outer layer 28 is simply bonded to the lower peripheral edge of shell 26 with a band of adhesive 30. Suitable adhesives include, for example, 3M double sided VHB tape, 3M adhesive type 10/99, Loctite cyanoacrylate and epoxy resin. Alternatively, conventional mechanical fixing means could be employed. Outer layer 28 is otherwise unattached and thus free to move relative to the shell 26 so as to mimic the protective movement of the scalp 18. A lubricant such as an oil or grease (with or without additives such as molybdenum disulphide) or other low friction element such as a layer of PTFE may be applied to either one or both facing surfaces or interposed (not shown) between outer layer 28 and the shell 26 so as to reduce friction and aid relative movement therebetween.

Upon impact, force components  $\beta$  normal to the helmet 20 cause elastic compression of the outer layer 28 in a normal direction, thus absorbing and dissipating energy. Tangential force components  $\alpha$  induce shear forces in the outer layer 28.

With an outer layer 28 which is substantially inelastic in shear, provided the magnitude of shear force does not exceed the shear strength of the adhesive 30 or that which causes the material of outer layer 28 to yield and/or tear, these shear forces are transmitted directly via the adhesive bond 30 to the hard shell 26. However, if the magnitude of an impact is such that the shear stress induced in the outer layer 28 exceeds the shear strength of the adhesive band 30 or the yield and/or tear strength of the

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material of outer layer 28, then failure of the band 30 or yielding or tearing of the outer layer 28 (or possibly all three) will occur. In this situation, outer layer 28 is free to move relative to the hard shell 28 and provides a low friction surface between the source of the impact and the hard shell 26 which permits relative movement therebetween. This so-called "failure" mode is deliberate and is effective in countering the tangential force component  $\alpha$ , limiting or preventing the resultant rotational forces from being imparted to the rest of the safety helmet 20 attached to a user's head 10. This is important in reducing or eliminating the transmission of rotational forces via the helmet 20 to the brain 12.

Alternatively, with an outer layer 28 which is substantially elastic in shear, provided the magnitude of shear force does not exceed the shear strength of the adhesive 30 or that which causes the material of outer layer 28 to yield or tear, these shear forces are transmitted via the adhesive bond 30 to the shell 26, but typically to a lesser degree than the actual forces received. The level of transmission of the shear forces from the outer layer 28 to the shell 26 varies in dependence upon the energy dissipated in the elastic stretching and relaxing of the outer layer 28. If the outer layer 28 is stretched on impact (e.g. with a road surface) but relaxes when the helmet 20 is no longer in contact with the source of the impact or another body, there will be no reactionary force other than within the outer layer 28 and thus little or no recoil of the helmet 20, and energy dissipation will occur. This is because outer layer 28 is free to move relative to the shell 28 and provides a low friction surface between the source of the impact and the hard shell 26 which permits relative movement therebetween. However, if the magnitude of an impact is such that

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the shear stress induced in the outer layer 28 exceeds the shear strength of the adhesive band 30 or the yield and/or tear strength of the material of outer layer 28, then failure of the band 30 or yielding and/or tearing of the outer layer 28 (or possibly all three) will occur. In this situation, outer layer 28 is free to move relative to the hard shell 28 and provides a low friction surface between the source of the impact and the shell 26 which permits relative movement therebetween.

These "failure" (operating) modes are effective in countering the tangential force component  $\alpha$ , limiting or preventing the resultant rotational forces from being imparted to the rest of the safety helmet 20 attached to a user's head 10. This is important in reducing or eliminating the transmission of rotational forces via the helmet 20 to the brain 12. Studies have indicated that rotational forces which result in a level of brain stress in excess of 20Kpa can cause damage to the human brain. Thus, for the purposes of the present invention, the 20Kpa brain stress figure represents a critical threshold. Accordingly, the shear strength of the adhesive band 30 and/or the material chosen for outer layer 28 will be selected deliberately with this in mind (i.e. to fail below the critical threshold causing brain stresses of 20Kpa) since this is clearly a very important factor in preventing brain damage from occurring in an impact.

Figure 11 is a schematic representation illustrating preferred stress/strain characteristics of the failure modes described above. Referring first to the embodiment having an inelastic outer layer 28, the stress (y-axis) can be seen to increase with a marginal increase in strain (x-axis) until a point A which represents failure of the adhesive band 30 or

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yielding and/or tearing of the outer layer 28. Beyond this point, the "extension" component of strain tends to infinity. Secondly, referring to the embodiment having an elastic outer layer 28, the stress can be  
5 seen to increase with increasing strain until a point B which represents failure of the adhesive band 30 or yielding and/or tearing of the outer layer 28. Beyond this point, the "extension" component of strain tends to infinity.

10

It must be stressed that the schematic of Figure 11 (and indeed of Figures 12 and 13 referred to below) is a schematic for illustrative purposes only. It does not reflect exact performance characteristics  
15 which will of course vary in dependence on the particular combination of materials selected for the helmet 20.

Alternative methods of attaching outer layer 28 to the hard shell 26 are illustrated in Figures 6a, 6b and 6c where, for the sake of simplicity and clarity, inner liner 24 within the shell 26 is not shown. Referring first to Figure 6a, the outer layer 28 can be seen to comprise protrusions 31 terminating in  
20 flanged heads 32 which pass through mating apertures provided in the shell 26. The flanged heads 32 lie adjacent to the inner surface of shell 26, retaining the outer layer 28 in position. The flanged heads 32 together with protrusions 31 maintain the outer layer  
25 28 in position until failure occurs at a designated shear strength, e.g. of a level giving rise to brain stresses of 20Kpa or less. This arrangement obviates the need for an adhesive (although in certain circumstances an adhesive may of course be used in  
30 conjunction with such a joint).

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- 20 -

A similar arrangement is illustrated in Figure 6b. However, in place of the flanged heads 32, an entire inner layer 33 is provided so as to retain outer layer 28 in position over the hard shell 26.

5 The protrusions 31 and inner layer 33 are designed such that failure of the protrusions 31 occurs at a designated shear strength, e.g. of a level giving rise to brain stresses of 20Kpa or less. Again, this arrangement can forgo the need for an adhesive.

10 Furthermore, the presence of an entire inner layer 33 may be beneficially employed as an inner liner 24, thus eliminating the need for a separate additional inner liner.

15 A yet further arrangement is illustrated in Figure 6c. In this arrangement, the shell 26 is formed with dovetail tenons 34 which are designed to interface with mating dovetail tenons formed in outer layer 28. Failure of these interfaces is designed to

20 occur at a designated shear strength, e.g. of a level giving rise to brain stresses of 20Kpa or less. Once again, this arrangement may obviate the need for an adhesive.

25 In each of the arrangements illustrated in Figures 6a, 6b and 6c, outer layer 28 is preferably formed directly on the shell 26 using, for example, in-mould, co-mould or two-shot manufacturing methods. These conventional methods, well known in the art,

30 ensure exacting tolerances are met reliably and consistently so as to ensure the desired failure modes (e.g. as described above). The attachment of outer layer 28 to the shell 26 in each case may occur solely at the lower peripheral edge of the shell 26, as

35 illustrated in Figures 7a and 7b or in regions all over the surface of the shell 26, as illustrated in Figure 7c. The arrangement illustrated in Figure 7c

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effectively "spot welds" the outer layer 28 to the shell 26. Such an arrangement can of course be achieved in the Figure 4 embodiment described above by using adhesive at each desired attachment location.

5

Whilst a threshold brain stress level of 20Kpa is the critical figure above which brain damage has been found to occur, it may of course be desirable (indeed preferable) to design to a much lesser figure at which the particular failure mode occurs (e.g. of a level giving rise to brain stresses of, say, 5, 10, or 15Kpa). Furthermore, it may be preferable in certain applications to provide a method of attachment which fails progressively at levels equivalent to brain stress levels of, for example, 5, 10, 15 and 20Kpa, either in a direction from the vertex of the helmet 20 towards the lower peripheral edge of the helmet 20, or otherwise. Such an arrangement is illustrated in Figure 7a, where smaller diameter apertures in the hard shell 26 house correspondingly sized diameter of protrusions 31 of outer layer 28. These aperture/protrusion combinations increase in diameter towards the lower peripheral edge of the helmet 20 to achieve the desired mode of incremental failure in an impact.

25

Figures 8a and 8b are detail views illustrating an alternative embodiment of outer layer 28 which is employed to obtain a particular characteristic of relative motion between it and the shell 26 before failure, as will now be described with reference to Figure 12.

30

Outer layer 28 is attached to the shell 26 around the lower peripheral edge thereof in a similar fashion to that described above and illustrated in Figures 4 and 5, i.e. by bonding with an adhesive band

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30 (although the other methods of mechanical attachment described above are equally applicable). However, outer layer 28 is additionally provided with an intermediary band 40 of concertina form. The intermediary band 40 may be formed as integral part of outer layer 28 or as a separate part attachable thereto. The intermediary band 40 configured so as to be proximal to the lower peripheral edge of helmet 20. In the case of a substantially inelastic outer layer 28, the intermediary band 40 retains the outer layer 28 taught over the shell 26 as illustrated in Figure 8a. Upon impact, intermediary band 40 undergoes plastic deformation and expands as illustrated in Figure 8b, permitting relative movement of outer layer 28 with respect to hard shell 26 before ultimate failure occurs in the usual way described above (once the intermediate band 40 has reached its full extension). In the case of a substantially elastic outer layer 28, the intermediary band 40 is naturally biased so as to retain the outer layer 28 taught over the shell 26 as illustrated in Figure 8a. Upon impact, intermediary band 40 undergoes elastic deformation and expands as illustrated in Figure 8b, permitting relative movement of outer layer 28 with respect to shell 26 before ultimate failure occurs in the usual way describe above (once the intermediate band 40 has reached its full extension).

These failure modes are illustrated in Figure 12, a schematic representation illustrating preferred stress/strain characteristics. Referring first to the embodiment having an inelastic outer layer 28, the strain (x-axis) can be seen to increase with a marginal increase in stress (y-axis) until the intermediary band 40 reaches full extension at point A. After this point, the stress can be seen to increase with marginal increases in strain until a



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point B which represents failure of the adhesive band 30 or yielding and/or tearing of the outer layer 28. Beyond this point, the "extension" component of strain tends to infinity. Secondly, referring to the  
5 embodiment having an elastic outer layer 28, the stress can be seen to increase with increasing strain until a point C which represents failure of the adhesive band 30 or yielding and/or tearing of the outer layer 28. Beyond this point, the "extension"  
10 component of strain tends to infinity.

The intermediary band 40 may consist of the same material as outer layer 28 or may be formed of a material having greater or lesser compliance than the  
15 outer layer 28. The outer layer 28 is attached to the shell 26 only via the intermediary band 40 and thus the remainder of the outer layer 28 is free to move relative to the underlying shell 26. The intermediary band 40 need not be of concertina form but may instead  
20 take any form which provides a specified region for plastic or elastic deformation of outer layer 28 on impact.

A layer of lubricant gel or other friction  
25 reducing material may be provided between the outer layer 28 and the shell 26 and this facilitates relative movement between the outer layer 28 and the shell 26. Suitable lubricants and friction reducing materials include (but are not limited to) silicone,  
30 Kluber paint on PTFE, molybdenum grease and Kluber food grade grease.

A further embodiment of helmet 20 is illustrated in Figure 9a, 9b and 9c. In this embodiment the outer  
35 layer 28 is also provided with an intermediary band 40 attached to the shell 26 in a similar fashion to that described above and illustrated in Figures 8a and 8b.

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However, an additional peripheral band of adhesive 32 or other means of fixing is provided in a generally proximal location, but more distal than the intermediary band 40, as is best illustrated in Figure 9a. The outer layer 28 is attached to the shell 26 only via the adhesive bands 30, 32 and thus outer layer 28 is otherwise free to move relative to the shell 26. Preferably, however, the additional adhesive band 32 is designed to have a lower shear strength equivalent to brain stress levels of, say, 10Kpa. Thus, under the action of an impact to the helmet 20 which generates brain stress levels of up to 10Kpa, the mode of operation of outer layer 28 is similar to that for the embodiments illustrated in Figures 4 and 5. However, should the shear stress level attained in the outer layer 28 exceed a level equivalent a brain stress level of 10kpa, the adhesive band 32 will shear, resulting in a subsequent mode of operation of outer layer 28 similar to that for the Figure 8a and 8b embodiments illustrated and described above. Again, the relative movement may be assisted by the interposition of a low friction surface (e.g. PTFE) or other lubricating layer between the outer layer 28 and the shell 26.

25

These failure modes are illustrated in Figure 13, a schematic representation illustrating preferred stress/strain characteristics. Referring first to the embodiment having an inelastic outer layer 28, the stress (y-axis) can be seen to increase with a marginal increase in strain (x-axis) until a point A which represents failure of the adhesive band 32, following which the strain can be seen to increase with a marginal increase in stress until the intermediary band 40 reaches full extension at point C. After this point, the stress can be seen to increase with a marginal increase in strain until a

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point D which represents failure of the adhesive band 30 or yielding and/or tearing of the outer layer 28. Beyond this point, the "extension" component of strain tends to infinity. Secondly, referring to the

5     embodiment having an elastic outer layer 28, the stress can be seen to increase with increasing strain until a point B which represents failure of the adhesive band 32, following which the strain can be seen to increase with increasing stress until the

10    intermediary band 40 reaches full extension at point C. After this point, the stress can be seen to increase with increasing strain until a point which represents failure of the adhesive band 30 or yielding and/or tearing of the outer layer 28. Beyond this

15    point, the "extension" component of strain tends to infinity.

A further embodiment of helmet 20 is illustrated in Figure 10a and 10b. In this embodiment the outer

20    layer 28 is provided with an intermediary band 40 and attached to the shell 26 in a similar fashion to that described above and illustrated in Figures 8a and 8b. However, instead of providing an additional band of adhesive 32 as illustrated in Figures 9a, 9b and 9c, a

25    shearable band 29 is provided in parallel with the intermediate band 40. This shearable band 29, like the adhesive band 32, is designed to have a shear strength equivalent to brain stress levels of, say 10Kpa. Thus, under the action of an impact to the

30    helmet 20 which generates brain stress levels of up to 10Kpa, the mode of operation of outer layer 28 is similar to that for the embodiment illustrated in Figures 4 and 5. However, should the shear stress level attained in the outer layer 28 reach or exceed a

35    level equivalent to brain stress levels of 10kpa, the shearable band 29 will shear, resulting in a mode of operation of the outer layer 28 similar to that for

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the Figure 8a and 8b embodiment illustrated and described above.

These failure modes are also depicted by Figure 13. Referring first to the embodiment having an inelastic outer layer 28, the stress (y-axis) can be seen to increase with a marginal increase in strain (x-axis) until a point A which represents failure of the shearable band 29, following which the strain can be seen to increase with a marginal increase in stress until the intermediary band 40 reaches full extension at point C. After this point, the stress can be seen to increase with a marginal increase in strain until a point D which represents failure of the adhesive band 30 or yielding and/or tearing of the outer layer 28. Beyond this point, the "extension" component of strain tends to infinity. Secondly, referring to the embodiment having an elastic outer layer 28, the stress can be seen to increase with increasing strain until a point B which represents failure of the shearable band 29, following which the strain can be seen to increase with increasing stress until the intermediary band 40 reaches full extension at point C. After this point, the stress can be seen to increase with increasing strain until a point which represents failure of the adhesive band 30 or yielding and/or tearing of the outer layer 28. Beyond this point, the "extension" component of strain tends to infinity.

It should be noted that the materials listed above as being suitable for outer layer 28 and the shell 26 are exemplary and not limiting, since the important criteria in each case is the particular arrangement of materials and the interaction of each's mechanical properties in arriving at a helmet 20 which mimics the protective features of the human head 10.

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It will be appreciated that ongoing work in the field of materials science will yield new materials or new combinations of existing materials (not to mention manufacturing techniques) which are equally  
5 appropriate for use in the present invention.

In all of the above embodiments, the inwardly facing surface of outer layer 28 and the outwardly facing surface of shell 26 may incorporate a lubricant  
10 or friction reducing material to dispense with the need for an intermediary layer such as a lubricant gel or friction reducing layer.

Substantial testing has been carried out on  
15 embodiments of helmet according to the invention, and very significant reductions were achieved in the maximum tangential force transmitted by the safety helmet 20 to the head 10 of a user. Also, a moderate decrease in the maximum linear acceleration forces was  
20 achieved.

The combination of materials for the headgear will be chosen bearing in mind that the sound insulation qualities of the combination may represent  
25 a hazard in motorcycle or pedal cycle applications. It is always possible to provide perforations in the ear area of the protective headgear.

In military/aeronautical applications additional  
30 material or earcups would provide noise protection and additional protection against lateral blows which tend to cause fractures of the base of the skull. Also visual protection and enhancement devices could be incorporated in the helmet and also respiratory  
35 devices such as gas masks and air purifiers.

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Since the heat insulation qualities of the described helmets could be high if certain material combinations are chosen, provision must be made for ventilation in appropriate weather conditions. Inlet  
5 and outlet ports will be provided with variable control of the air inlet and consideration will be given to the provision of ventilation ports on the vertex in applications where there is no generated air flow.

10 In many accidents, particularly in industrial mishaps involving a fall, the helmet is flung off. The retention system is, therefore, a critical element of head protection. On each side of the helmet 20 there is preferably a two point attachment, one in front and the other behind the central transverse  
15 vertical plane. Typically, there is provided either a double strap 21 joined to form a chin strap or cup, or a single strap from each point of attachment, the anterior strap providing a chin restraint and the  
20 posterior strap an occipital restraint. The retention system will inevitably depend on the shape of the helmet and its particular application.

A further aspect of the present invention is the  
25 conversion of existing "hard hats" to hats with "soft" outer skins according to the invention, preferably with the provision of effective retention systems. Soft covers and new retention systems designed for attachment to existing headgear are included in the  
30 scope of the invention. Furthermore, it is envisaged that interchangeable or replaceable outer layers may be produced for use with the various embodiments of the present invention. Essentially, the outer layers will be produced in various colours and graphic  
35 designs, rather like replacement covers for mobile telephones. It is not recommended that these outer layers be used to replace "damaged" outer layers since

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the structural integrity of remainder of the helmet 20 may have been compromised, even if such damage is not readily visible to the eye.

5           Whilst above the present invention is described with reference to its use for protective headgear, the invention can also be applied to protective armour, such as body armour. The same principle of using an  
10 of attachment to a base plate of the armour, and the various "failure" modes described above.

Referring to Figure 14, there is illustrated protective armour in the form of a breast plate 100  
15 which can be worn in front of a user and secured by straps 101. Figure 15 illustrates a cross section through the protective armour of Figure 14, the breast plate 100 comprising a base layer 102 which has a first surface which in use is presented to receive  
20 impact blows. The armour also comprises an outer layer 104 which overlies the first surface of the base layer 102. Outer layer 104 is designed to resemble the scalp 18. Accordingly, in a first embodiment, there is provided an outer layer 104 which is  
25 substantially inelastic in shear but elastically compressible when subjected to forces in the normal direction (similar to the scalp 18). However, it has been found in testing that a second embodiment comprising an outer layer 104 which is substantially  
30 elastic both in shear and when subjected to forces in the normal direction can also be effective. The base layer 102 mimics the skull 16 and thus provides a hard surface for energy dissipation whilst allowing a degree of compression or crushing to facilitate  
35 increased energy absorption. Suitable materials for the outer layer 104 and base layer 102 include those

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listed and described above for the protective headgear.

5       The outer layer 104 may be attached to the base layer 102 in a similar fashion to, and using any of the mechanisms described above for the protective headgear. These embodiments are illustrated in Figures 16a, 16b, 16c, 16d and 16e.

10       An intermediary layer of lubricant gel may beneficially be included between the outer layer 104 and the base layer 102 and facilitates relative motion between them. This layer is not essential and could be replaced by a solid layer of a material of a low  
15       coefficient of friction (e.g. a layer of PTFE). Alternatively a lubricant could be incorporated into the inner surface of one or other or both of the outer layer 104 and base layer 102.

20       The protective armour is constructed in such a way that when the components of force of an impact are received by the outwardly facing surface of the outer layer 104, the mode of dissipating and absorbing the energy is identical to that for the protective  
25       headgear described above.

30       The present invention also provides a method of modifying protective armour comprising providing a "soft" outer layer to cover an existing base plate.

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**CLAIMS**

1. Protective headgear comprising:  
a shell having an inwardly facing surface which  
5 in use faces the head of a user of the headgear and an  
outwardly facing surface which in use faces away from  
the head of a user;  
an outer layer which overlies at least a portion  
of the outwardly facing surface of the shell; and  
10 rupturing means for fixedly attaching the outer  
layer to the remainder of the headgear at one or more  
locations, wherein:  
the rupturing means is configured so as to fail  
when a force greater than a selected threshold is  
15 received on an outer surface of the headgear which  
acts in an at least part tangential direction to  
rotate the headgear and the head of the user, and  
upon failure of the rupturing means at the one or  
more locations, the received force causes at least  
20 part of the outer layer receiving the force to move  
relative to the shell in a manner which is similar to  
the protective movement of the human scalp relative to  
the skull.
- 25 2. Protective headgear as claimed in claim 1 wherein  
the rupturing means is a discreet item interposed  
between the shell and the outer layer.
3. Protective headgear as claimed in claim 1 wherein  
30 the rupturing means is an integral part of the outer  
layer.
4. Protective headgear as claimed in claim 1 wherein  
the rupturing means is an integral part of the shell.

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5. Protective headgear as claimed in any one of the preceding claims wherein the rupturing means comprises an adhesive.
- 5 6. Protective headgear as claimed in claim 5 wherein the adhesive comprises any one or combination of 3M double sided VHB tape, 3M adhesive type 10/99, Loctite cyanoacrylate or epoxy resin.
- 10 7. Protective headgear as claimed in any one of claims 1 to 4 wherein the rupturing means comprises mechanical fastening means.
- 15 8. Protective headgear as claimed in any one of the preceding claims wherein the rupturing means is graduated so as to fail incrementally, with partial failure of the rupturing means occurring at a force less than the selected threshold and partial failure continuing with increasing force until total failure of the rupturing means occurs at the selected threshold.
- 20 9. Protective headgear as claimed in claim 8 wherein graduation of the rupturing means is achieved by varying the strength or interface characteristics of the rupturing means at one or more attachment locations.
- 25 10. Protective headgear as claimed in any one of the preceding claims wherein the outer layer is substantially inelastic in shear.
- 30 11. Protective headgear as claimed in claim 10 wherein the outer layer undergoes plastic deformation prior to failure of the rupturing means when a force less than the selected threshold is received on the outer surface of the headgear.
- 35

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12. Protective headgear as claimed in claim 11  
wherein the outer layer is provided with regions for  
localised plastic deformation on receiving a force  
which is less than the force required to cause the  
5 rupturing means to fail.

13. Protective headgear as claimed in claim 12  
further comprising additional rupturing means which is  
configured to fail at a selected threshold lower than  
10 that selected for the rupturing means.

14. Protective headgear as claimed in claim 13  
wherein the additional rupturing means prevents  
plastic deformation of the outer layer until the  
15 additional rupturing means fails.

15. Protective headgear as claimed in any one of  
claims 1 to 9 wherein the outer layer is substantially  
elastic in shear.  
20

16. Protective headgear as claimed in claim 15  
wherein the outer layer undergoes elastic deformation  
prior to failure of the rupturing means when a force  
less than the selected threshold is received on the  
25 outer surface of the headgear, the outer layer  
receiving the force less than the selected threshold  
moving relative to the shell in a manner which is  
similar to the protective movement of the human scalp  
relative to the skull.

17. Protective headgear as claimed in claim 16  
wherein the outer layer is provided with regions for  
localised elastic deformation which deform elastically  
at a force less than that required to cause elastic  
35 deformation of the remainder of the outer layer, the  
force received being one which is less than the force  
required to cause the rupturing means to fail.

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18. Protective headgear as claimed in claim 17  
further comprising additional rupturing means which is  
configured to fail at a selected threshold lower than  
that selected for the rupturing means.

5

19. Protective headgear as claimed in claim 18  
wherein the additional rupturing means prevents  
elastic deformation of the outer layer in the regions  
for localised elastic deformation until the additional  
rupturing means fails.

10

20. Protective headgear as claimed in any one of  
claims 13, 14, 18 or 19 wherein the additional  
rupturing means comprises an adhesive.

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21. Protective headgear as claimed in any one of  
claims 13, 14, 18 or 19 wherein the additional  
rupturing means comprises a shearable band.

20

22. Protective headgear as claimed in any one of the  
preceding claims wherein the shell comprises a  
composite material.

25

23. Protective headgear as claimed in any one of the  
preceding claims wherein the shell comprises a  
laminate structure.

30

24. Protective headgear as claimed in any one of the  
preceding claims wherein the shell comprises any one  
or more of polypropylene, polycarbonate, ABS,  
polycarbonate/ABS blend, high density polyethylene  
(HDPE), carbon fibre composites, glass reinforced  
plastics, Zytel (a nylon manufactured by DuPont),  
Celstran (a long strand glass, carbon or aramid fibre  
material in a modulus carrier such as polypropylene,  
polyethylene, polycarbonate, ABS, TPU or nylon),  
Twintex (glass fibre reinforced polypropylene

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manufactured by Vetrotex), Curv PP (a polypropylene fibre reinforced material manufactured by BP), or Kevlar composites (aramid fibres in a resin carrier).

- 5      25. Protective headgear as claimed in any one of the preceding claims wherein the outer layer comprises a composite material.
- 10      26. Protective headgear as claimed in any one of the preceding claims wherein the outer layer is a laminate structure.
- 15      27. Protective headgear as claimed in any one of the preceding claims wherein the outer layer comprises any one or more of thermoplastic elastomers such as Santoprene (manufactured by Advanced Elastomer Systems in a range of grades), Hytrel in a solid or foamed form, thermoset elastomers such as polyurethane elastomers (typically in the hardness range 50 shore A to 70 shore D), High Q (a rubber manufactured by Astron), sorbothane, natural or synthetic rubbers or plasticised foams, low or high density polyethylene (LDPE or HDPE) or conventional thermoplastic or thermosetting plastics.
- 20      28. Protective headgear as claimed in any one of the preceding claims wherein the outer layer is reinforced with high stiffness, low elongation fibres such as glass, carbon or aramid (Kevlar) fibres so as to reduce the overall elasticity of the outer layer.
- 25      29. Protective headgear as claimed in any one of the preceding claims further comprising a layer of low density foam located between the shell and the head of a user.
- 30      35

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30. Protective headgear as claimed in any one of the preceding claims further comprising a layer of incompressible fluid located between the shell and the head of a user and encapsulated in a flexible sac.

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31. Protective headgear as claimed in claim 30 wherein the flexible sack containing incompressible fluid is compartmentalised into a plurality of compartments and the flexible sack comprises connection means connecting each compartment to at least one other compartment, the connection means being operable to prevent flow of fluid from one compartment to another until an impact on the outer surface of the headgear exceeds a threshold value at which point the connection means allows flow of fluid between the compartments.

32. Protective headgear as claimed in claim 31 wherein the incompressible fluid is a fluid which resists flow between compartments in order to damp motion of the shell.

33. Protective headgear comprising:  
a shell having an inwardly facing surface which in use faces the head of a user of the headgear and an outwardly facing surface which in use faces away from the head of a user;

an outer layer which overlies at least a portion of the outwardly facing surface of the shell; and  
means for fixedly attaching the outer layer to the remainder of the headgear at one or more locations, wherein

the outer layer is configured so as to fail when a force greater than a selected threshold is received on an outer surface of the headgear which acts in an at least part tangential direction to the outer

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surface of the headgear to rotate the headgear and the head of the user, and

upon failure of the outer layer, the received force causes at least part of the outer layer  
5 receiving the force to move relative to the shell in a manner which is similar to the protective movement of the human scalp relative to the skull.

34. Protective headgear as claimed in claim 33  
10 wherein the means for fixedly attaching the outer layer to the remainder of the headgear at one or more locations comprises an adhesive.

35. Protective headgear as claimed in claim 34  
15 wherein the adhesive comprises any one or combination of 3M double sided VHB tape, 3M adhesive type 10/99, Loctite cyanoacrylate or epoxy resin.

36. Protective headgear as claimed in claim 33  
20 wherein the means for fixedly attaching the outer layer to the remainder of the headgear at one or more locations comprises mechanical fastening means.

37. Protective headgear as claimed in any one of  
25 claims 33 to 36 wherein the outer layer is substantially inelastic in shear.

38. Protective headgear as claimed in claim 37  
wherein the outer layer undergoes plastic deformation  
30 prior to failure of the means for fixedly attaching the outer layer to the remainder of the headgear at one or more locations.

39. Protective headgear as claimed in claim 37 or  
35 claim 38 wherein the outer layer is provided with regions for localised plastic deformation on receiving a force which is less than the force required to cause

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the means for fixedly attaching the outer layer to the remainder of the headgear at one or more locations to fail.

5      40. Protective headgear as claimed in any one of claims 33 to 36 wherein the outer layer is substantially elastic in shear.

10      41. Protective headgear as claimed in claim 40 wherein the outer layer undergoes elastic deformation prior to failure of the means for fixedly attaching the outer layer to the remainder of the headgear at one or more locations when a force less than the selected threshold is received on the outer surface of  
15      the headgear, the outer layer moving relative to the shell in a manner which is similar to the protective movement of the human scalp relative to the skull.

20      42. Protective headgear as claimed in claim 40 or claim 41 wherein the outer layer is provided with regions for localised elastic deformation which deform elastically at a force less than that required to cause elastic deformation of the remainder of the outer layer, the force received being one which is  
25      less than the force required to cause failure of the means for fixedly attaching the outer layer to the remainder of the headgear at one or more locations.

30      43. Protective headgear as claimed in any one of claims 33 to 42 wherein the shell comprises a composite material.

35      44. Protective headgear as claimed in any one of claims 33 to 43 wherein the shell comprises a laminate structure.



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45. Protective headgear as claimed in any one of claims 33 to 44 wherein the shell comprises any one or more of polypropylene, polycarbonate, ABS, polycarbonate/ABS blend, high density polyethylene (HDPE), carbon fibre composites, glass reinforced plastics, Zytel (a nylon manufactured by DuPont), Celstran (a long strand glass, carbon or aramid fibre material in a modulus carrier such as polypropylene, polyethylene, polycarbonate, ABS, TPU or nylon), Twintex (glass fibre reinforced polypropylene manufactured by Vetrotex), Curv PP (a polypropylene fibre reinforced material manufactured by BP), or Kevlar composites (aramid fibres in a resin carrier).
46. Protective headgear as claimed in any one of claims 33 to 45 wherein the outer layer comprises a composite material.
47. Protective headgear as claimed in any one of claims 33 to 46 wherein the outer layer is a laminate structure.
48. Protective headgear as claimed in any one of claims 33 to 47 wherein the outer layer comprises any one or more of thermoplastic elastomers such as Santoprene (manufactured by Advanced Elastomer Systems in a range of grades), Hytrel in a solid or foamed form, thermoset elastomers such as polyurethane elastomers (typically in the hardness range 50 shore A to 70 shore D), High Q (a rubber manufactured by Astron), sorbothane, natural or synthetic rubbers or plasticised foams, low or high density polyethylene (LDPE or HDPE) or conventional thermoplastic or thermosetting plastics.
49. Protective headgear as claimed in any one of claims 33 to 48 wherein the outer layer is reinforced

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with high stiffness, low elongation fibres such as glass, carbon or aramid (Kevlar) fibres so as to reduce the overall elasticity of the outer layer.

- 5      50. Protective headgear as claimed in any one of claims 33 to 49 further comprising a layer of low density foam located between the shell and the head of a user.
- 10     51. Protective headgear as claimed in any one of claims 33 to 50 further comprising a layer of incompressible fluid located between the shell and the head of a user and encapsulated in a flexible sac.
- 15     52. Protective headgear as claimed in any one of claims 33 to 51 wherein the flexible sack containing incompressible fluid is compartmentalised into a plurality of compartments and the flexible sack comprises connection means connecting each compartment
- 20     to at least one other compartment, the connection means being operable to prevent flow of fluid from one compartment to another until an impact on the outer surface of the headgear exceeds a threshold value at which point the connection means allows flow of fluid
- 25     between the compartments.
53. Protective headgear as claimed in claim 52 wherein the incompressible fluid is a fluid which resists flow between compartments in order to damp
- 30     motion of the shell.
54. Protective headgear as claimed in any one of claims 33 to 53 wherein upon failure of the outer layer, the headgear maintains levels of stress in the
- 35     brain below 20kpa.

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55. Protective headgear as claimed in any one of claims 1 to 32 wherein upon failure of the rupturing means, the headgear maintains levels of stress in the brain below 20kpa.

5

56. Protective armour comprising:

a base layer having an inwardly facing surface which in use faces the body of a user of the armour and an outwardly facing surface which in use faces away from the body of a user;

10

an outer layer which overlies at least a portion of the outwardly facing surface of the base layer; and rupturing means for fixedly attaching the outer layer to the remainder of the armour at one or more locations, wherein:

15

the rupturing means is configured so as to fail when a force greater than a selected threshold is received on an outer surface of the armour which acts in an at least part tangential direction to rotate the armour and the body of the user, and

20

upon failure of the rupturing means at the one or more locations, the received force causes at least part of the outer layer receiving the force to move relative to the base layer in a manner which is similar to the protective movement of the human scalp relative to the skull.

25

57. Protective armour comprising:

a base layer having an inwardly facing surface which in use faces the body of a user of the armour and an outwardly facing surface which in use faces away from the body of a user;

30

an outer layer which overlies at least a portion of the outwardly facing surface of the base layer; and

35

means for fixedly attaching the outer layer to the remainder of the armour at one or more locations, wherein:

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the outer layer is configured so as to fail when a force greater than a selected threshold is received on an outer surface of the armour which acts in an at least part tangential direction to the outer surface of the armour to rotate the armour and the body of the user, and

upon failure of the outer layer, the received force causes at least part of the outer layer receiving the force to move relative to the base layer in a manner which is similar to the protective movement of the human scalp relative to the skull.

58. A method of modifying existing protective headgear wherein:

an outer layer is provided to overlies at least a portion of an outwardly facing surface of the existing protective headgear; and

rupturing means are provided for fixedly attaching the outer layer to the remainder of the existing protective headgear at one or more locations, the rupturing means being configured so as to fail when a force greater than a selected threshold is received on an outer surface of the modified headgear which acts in an at least part tangential direction to rotate the modified headgear and the head of the user, and

upon failure of the rupturing means at the one or more locations, the received force causes at least part of the outer layer receiving the force to move relative to the outwardly facing surface of the existing protective headgear in a manner which is similar to the protective movement of the human scalp relative to the skull.

59. A method of modifying existing protective headgear wherein:

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an outer layer is provided to overlie at least a portion of an outwardly facing surface of the existing protective headgear; and

5 means is provided for fixedly attaching the outer layer to the remainder of the existing protective headgear at one or more locations,

the outer layer being configured so as to fail when a force greater than a selected threshold is received on an outer surface of the modified headgear which acts in an at least part tangential direction to the outer surface of the modified headgear to rotate the modified headgear and the head of the user, and

10 upon failure of the outer layer, the received force causes at least part of the outer layer receiving the force to move relative to the outwardly facing surface of the existing protective headgear in a manner which is similar to the protective movement of the human scalp relative to the skull.

20 60. A method of modifying existing protective armour wherein:

an outer layer is provided to overlie at least a portion of an outwardly facing surface of the existing protective armour; and

25 rupturing means are provided for fixedly attaching the outer layer to the remainder of the existing protective armour at one or more locations,

the rupturing means being configured so as to fail when a force greater than a selected threshold is received on an outer surface of the modified armour which acts in an at least part tangential direction to rotate the modified armour and the body of the user, and

30 upon failure of the rupturing means at the one or more locations, the received force causes at least part of the outer layer receiving the force to move relative to the outwardly facing surface of the

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existing protective armour in a manner which is similar to the protective movement of the human scalp relative to the skull.

5     61. A method of modifying existing protective armour wherein:

an outer layer is provided to overlie at least a portion of an outwardly facing surface of the existing protective armour; and

10     means is provided for fixedly attaching the outer layer to the remainder of the existing protective armour at one or more locations,

the outer layer being configured so as to fail when a force greater than a selected threshold is received on an outer surface of the modified armour which acts in an at least part tangential direction to the outer surface of the modified armour to rotate the modified armour and the body of the user, and

15     upon failure of the outer layer, the received force causes at least part of the outer layer receiving the force to move relative to the outwardly facing surface of the existing protective armour in a manner which is similar to the protective movement of the human scalp relative to the skull.

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FIG. 1

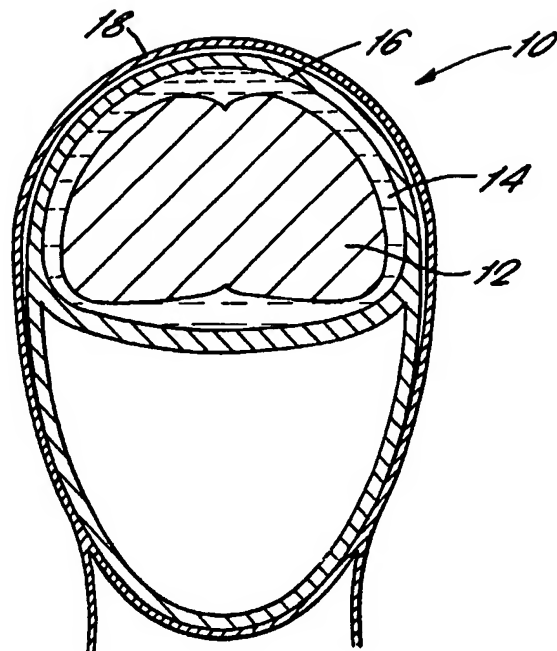
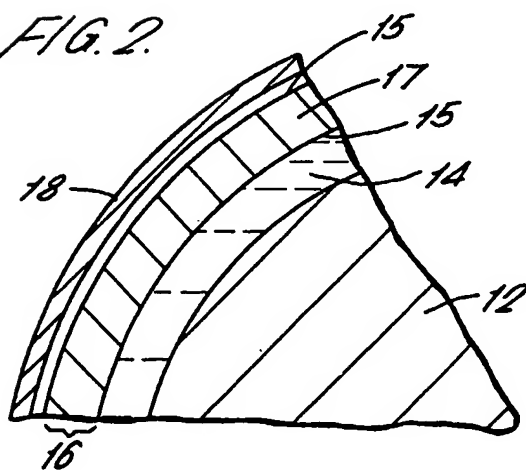
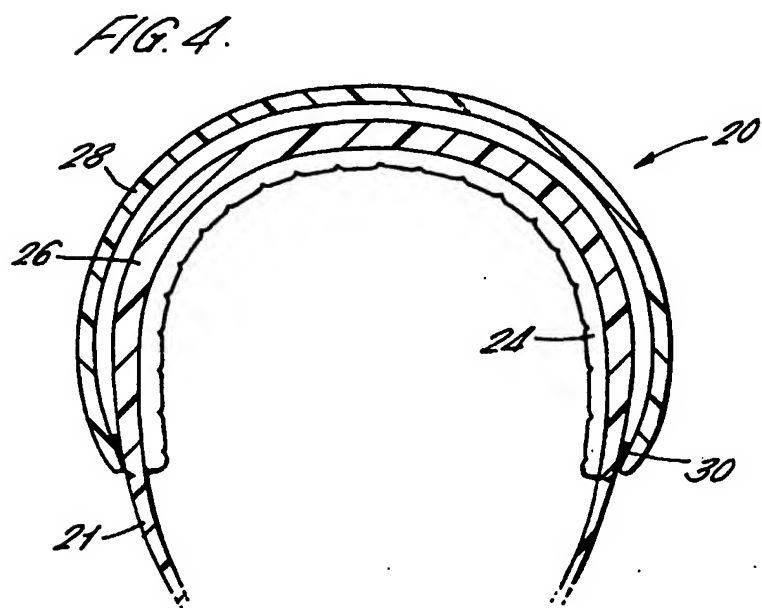
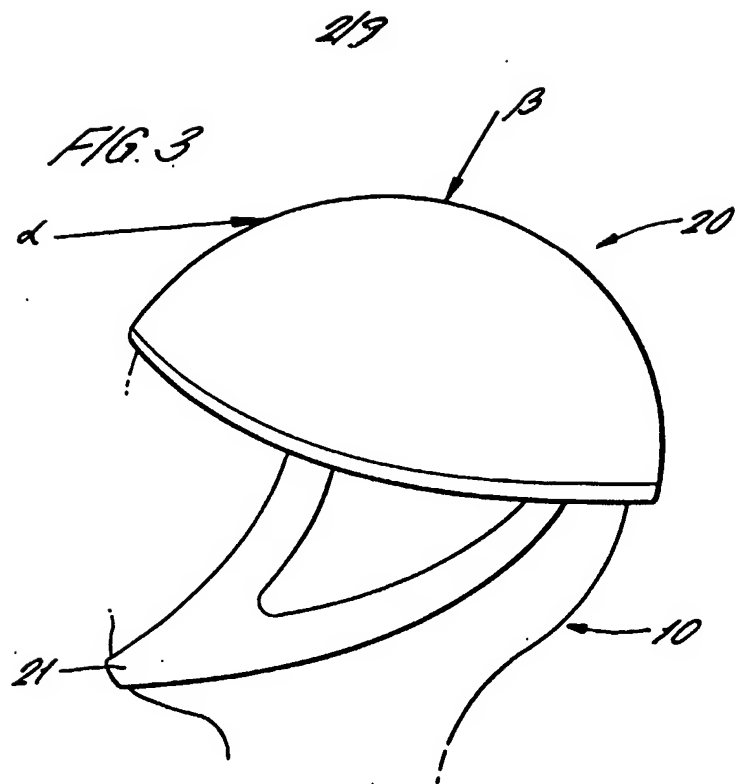


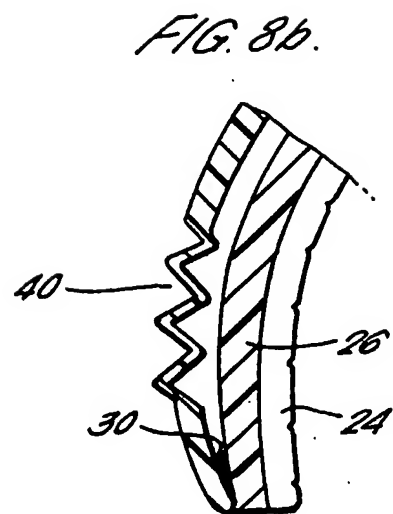
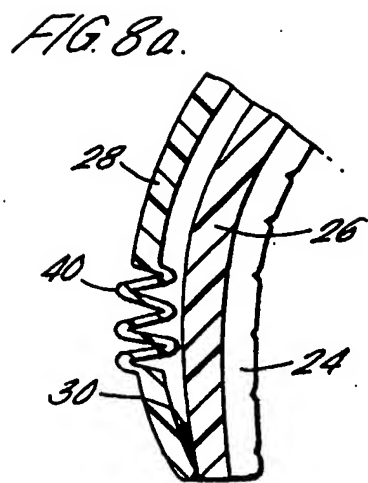
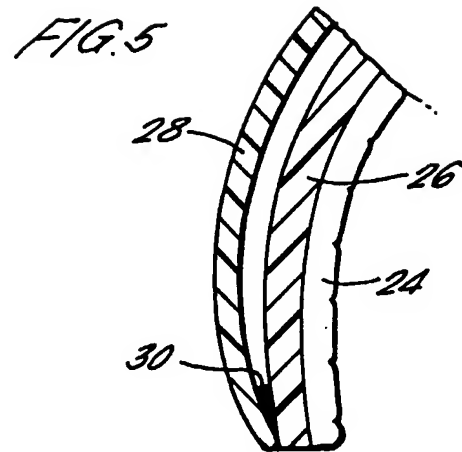
FIG. 2







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FIG. 6a.

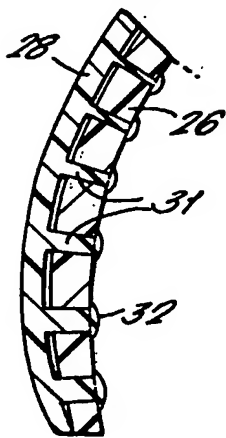


FIG. 6b.

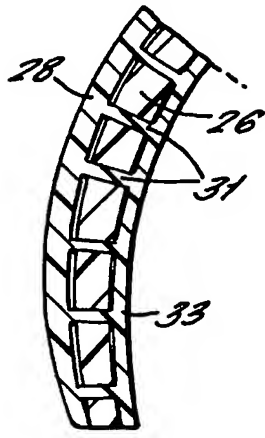


FIG. 6c.

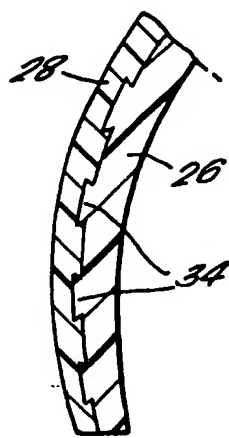


FIG. 7a.

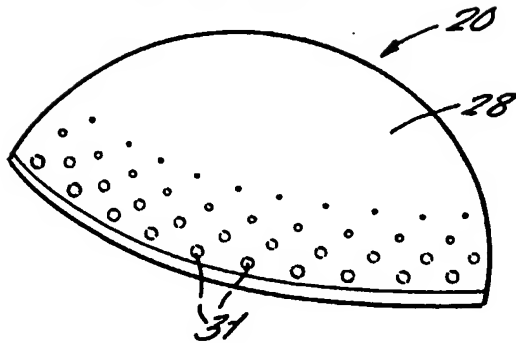


FIG. 7b.

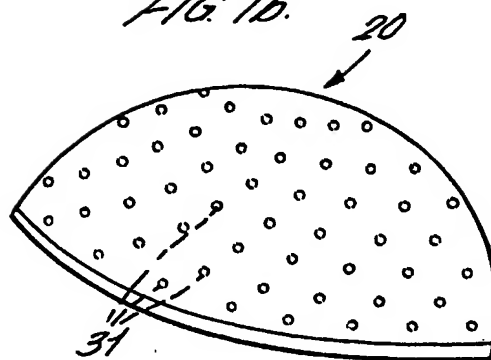
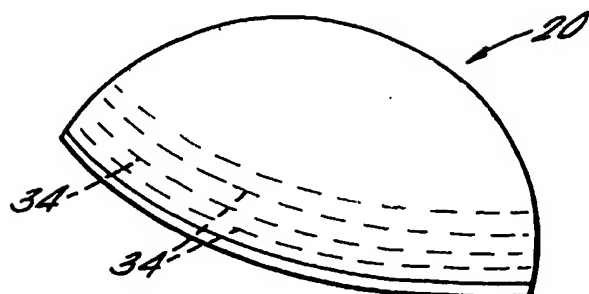


FIG. 7c.



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FIG. 9a.

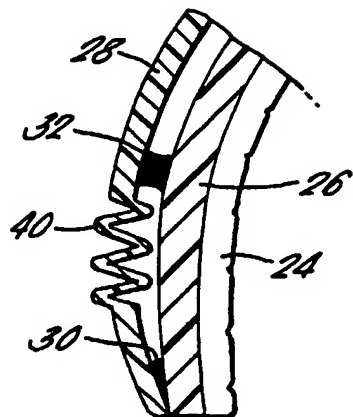


FIG. 9b.

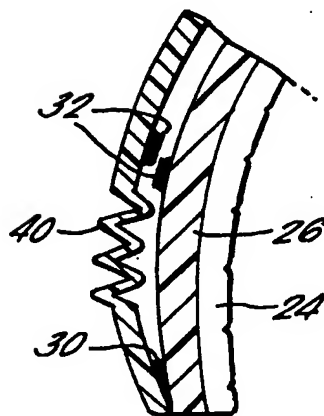
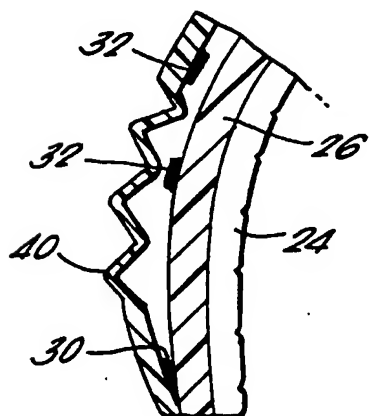


FIG. 9c.



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FIG. 10a.

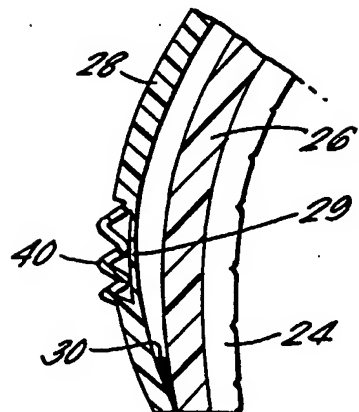
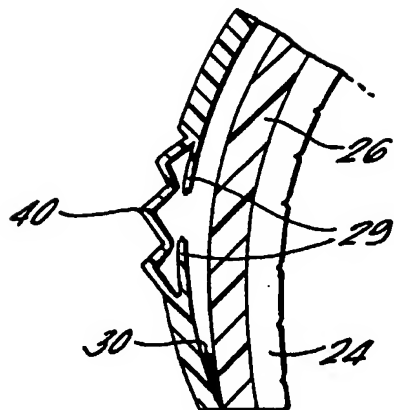
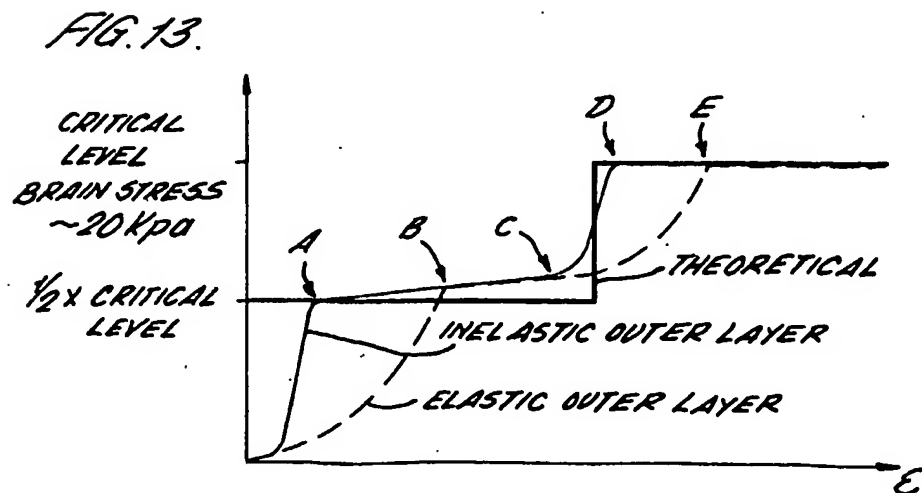
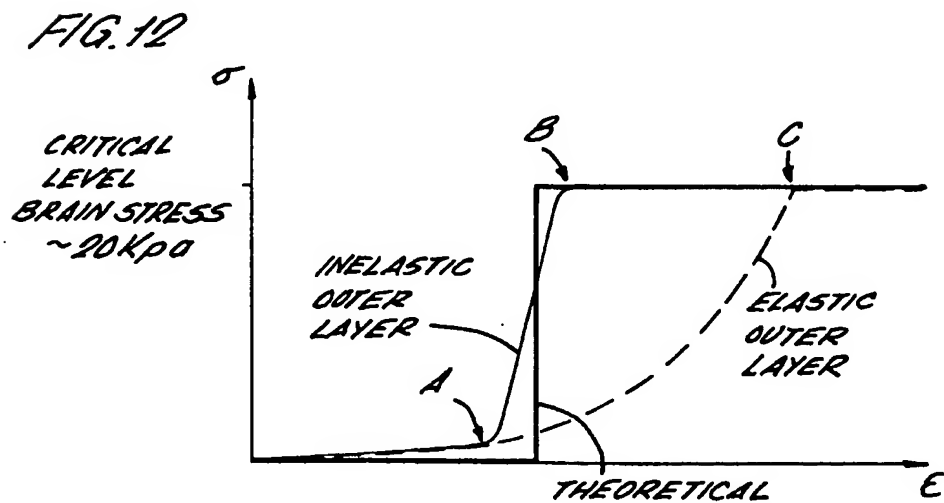
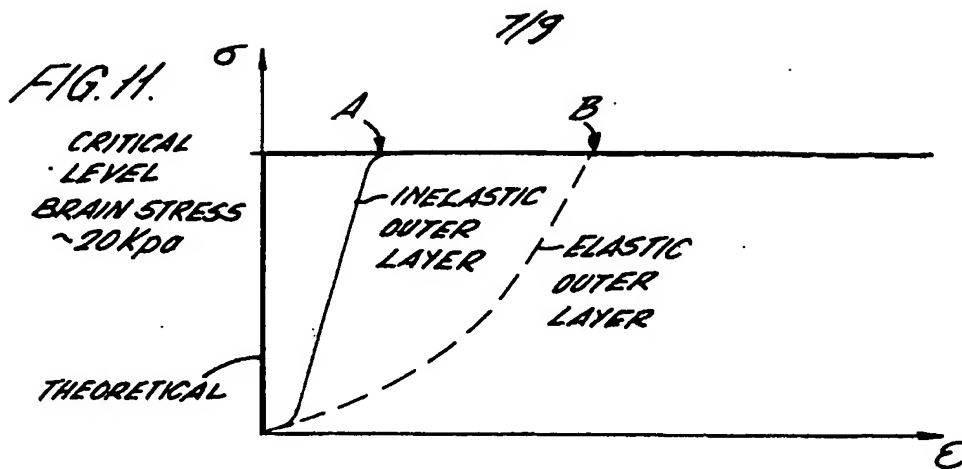


FIG. 10b.





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FIG. 14.

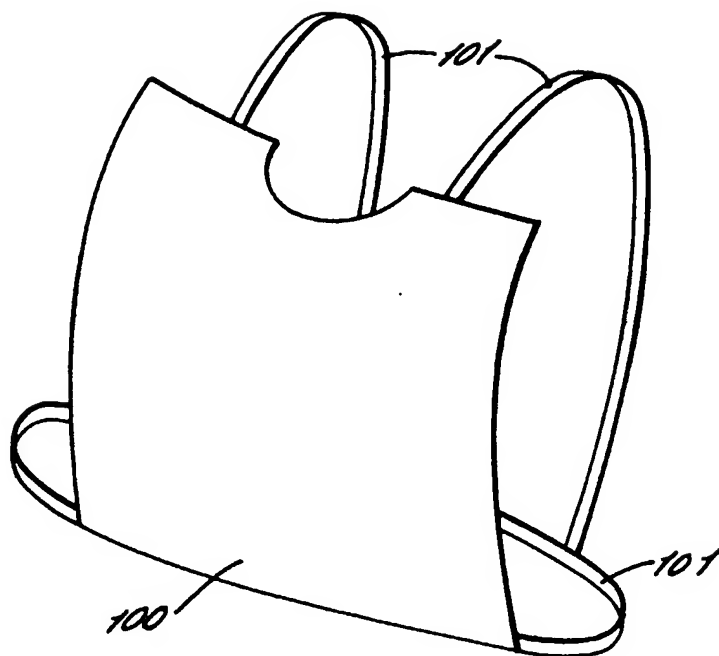
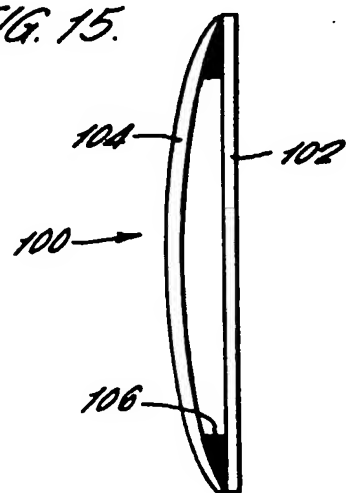


FIG. 15.



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FIG. 16a.



FIG. 16b.

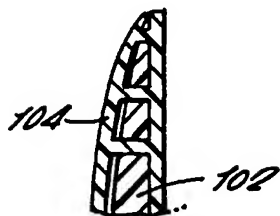


FIG. 16c.

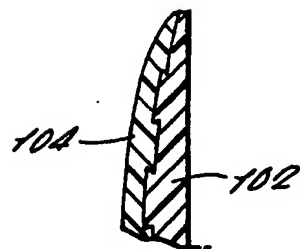


FIG. 16d.

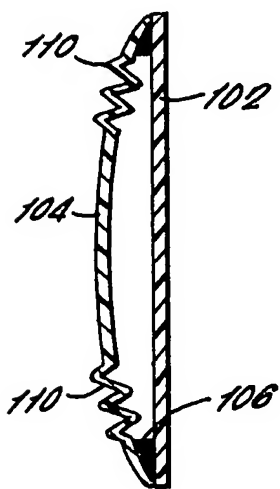
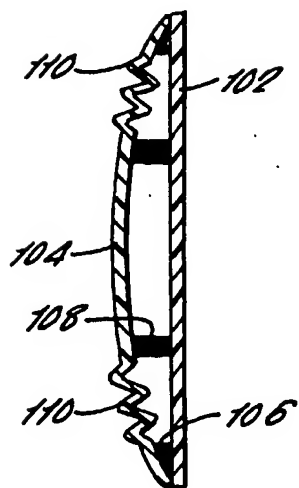


FIG. 16e.



## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 02/03139

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A42B3/06

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A42B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 96 14768 A (K. D. PHILLIPS) 23 May 1996 (1996-05-23) page 9, paragraph 3 -page 10, paragraph 2 page 14, paragraph 3 -page 15, paragraph 4 claim; figures 6-10	1-61
A	& EP 0 790 787 A 27 August 1997 (1997-08-27) cited in the application ---	
A	WO 01 45526 A (H. VON HOLST ; P. HALLDIN) 28 June 2001 (2001-06-28) page 4, line 10 -page 5, line 19 page 5, line 36 -page 6, line 16 page 7, line 16 -page 8, line 18 figures 1-3C, 7-10 ---	1-4, 7
A	US 4 307 471 A (DU PONT CANADA INC.) 29 December 1981 (1981-12-29) ---	
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Patent family members are listed in annex.

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Date of the actual completion of the international search

31 October 2002

Date of mailing of the international search report

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## INTERNATIONAL SEARCH REPORT

International Application No

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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